Supporting Undergraduate Courses on Electromagnetism by Field Simulation Exercises

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***Abstract*—Abstract This paper reports about experience with electromagnetic field simulation in first-year electromagnetism courses for heterogeneous groups of science, engineering and medical students.**

***Index Terms*—Electromagnetic field simulation, education, bachelor courses, electromagnetism.**

I. Simulation Exercise

The first two lectures in a common electromagnetism force deal with the Coulomb force, electric field and electric potential and illustrate this with the working principle of a cathode ray tube with deflection. The simulation exercise itself starts with a tutorial (half an hour) where the students are guided step-by-step to solve a simple electrostatic problem. Then, teams of two students, preferably of different disciplines, are formed. The teams draw the cathode-ray-tube geometry, which is simplified from the photograph of a real device (Fig. 1). They define materials, boundary conditions and excitations and carry out a first electromagnetic field simulation in about an hour [1]. At first, only the cathode and anode are excited. Electrons are omitted from cathode surface and tracked in the electric field. The students are stimulated to interpret the electric field plots and the energy changes of the tracked particles. They extract the field distribution along the centre line and write down some typical values on a result form. The students are suggested to change any simulation parameters and discuss changes. As a second task, the guiding text [2] summarises the relevant formulae for an analytical model. The formulae are provided in a worksheet. The students specialise the sheet for their particular device and evaluate the results. A two-column table invites them to compare analytical and numerical results. Selected question guide the students' interpretation of any discrepancies. The third task consists of simulations with a voltage drop between the deflection electrodes. Also here, a comparison with analytical results is asked for. The students get the opportunity to carry out changes to the geometry (e.g. rounding off sharp corners to prevent corona effects, optimising the cathode and anode geometries to decrease the loss of electrons). As a fourth task, every student team should tune the applied voltages to achieve an electron beam with a prescribed energy at a prescribed place on the screen. Finally, the coach summarises the exercise and gives a look forward on magnetic deflection coming in future lectures. The overall simulation exercise takes about four hours.

Fig. 1. Photograph and electron trajectories in a cathode ray tube.

II. Discussion and Conclusion

The photograph of an existing device as a starting point, the approach defining the model from scratch and the opportunity to change any model parameter are clearly the main motivating factors. Field simulation brings the field concept on the foreground [3]. However, active questioning by the coach is absolutely necessary to guide the students when interpreting field plots. The exercise compares analytical with simulation results. In practice, one of the students carries out the simulation, where the other student is concerned with the worksheet and the result form. The comparison automatically brings up a discussion between both students, which, when supervised by a coach, resulted in an increased learning efficiency [4]. The exercise has a beneficial influence on the perception of electrostatics. Especially, the interactive possibility to repeat simulations for slightly different configurations helped the students to get more familiar with the field concept.

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References

[1] Computer Simulation Technology AG, "CST EM Studio and Particle Studio." www.cst.com.
[2] H. De Gersem, "Simulation of a cathode ray tube." http://www.kuleuven-kortrijk.be/~u0005424/CathodeRayTube.pdf.
[3] D. Lowther and E. Freeman, "A new approach to using simulation software in the electromagnetics curriculum," *IEEE Transactions on Education*, vol. 36, pp. 219–222, May 1993.
[4] E. Mazur, *Peer Instruction: A User's manual*. Upper Saddle River, NY: Prentice Hall, 1997.